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Polymer solar cells based on MEH-PPV and PCBM

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Abstract

Polymer solar cells based on poly(2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene(MEH-PPV) and fullerene derivative [6,6]-phenyl-C₆₁-butyric acid methyl ester (PCBM) were fabricated by spin-coating. The improved performance has been achieved by blend polymer MEH-PPV with PCBM in a ratio of 1:4 by weight. The power conversion efficiency reached 1.3% under illumination of AM 1.5 with an incident power density of 78 mW/cm² in blend single layer polymer solar cells.

Keywords: Polymers, Fullerene, Solar cells,

1. Introduction

Polymer electronics has been developed very fast since conducting polymers were discovered in 1977 [1]. Conducting polymer materials have been used as an active medium in several opto-electronic devices, such as light emitting diodes (LED), field effect transistors, and photodiodes [2–4]. Currently, polymer solar cells have attracted a significant attention, because of light weight, flexibility and manufacturability when compared to the inorganic counterparts. Accordingly, various techniques have been developed for the improvement of the performance whereby the power conversion efficiency as high as 2.5% has been achieved using polymer/molecule blends as an active layer[5]. High molecular weight polymer poly(2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene (MEH-PPV), which is widely used in polymer light emitting diodes, is also an effective electron donor in polymer photodiodes. We reported earlier that stratified bi-layer photodiodes made of MEH-PPV and fullerene derivative [6,6]-phenyl-C₆₁-butyric acid methylester (PCBM) have good performance [6]. Here we present our recent work on further performance improvement of polymeric solar cells based on MEH-PPV and PCBM by modifying the structure of the devices.

2. Experimental

Patterned indium-tin-oxide(ITO) was cleaned and in

plasma for 20 seconds. Conducting polymer complex of poly(3,4- ethylenedioxythiophene) and poly(styrene sulfonate) (PEDOT-PSS) (Baytron P, Bayer AG) was spin-coated on the cleaned ITO and annealed at 120°C for 5 minutes as a buffer layer or polymer anode. The thickness of PEDOT-PPSS layer was about 100 nm. The blend of MEH-PPV and PCBM (1:4 by weight) was dissolved in chloroform (10 mg/ml). The blend solution was spin-coated on top of the PEDOT-PSS layer, followed by Al (60 nm) deposition using vacuum evaporation ($\sim 10^{-6}$ torr). For some of the devices, LiF (9 Å) was deposited prior to the Al layer deposition. The thickness of the active layers was about 100 nm and the device area was 7mm².

The photovoltaic characteristics of these solar cells were measured at room temperature and atmosphere by using a set-up consisted of a Keithley 485 picometer, an Oriel MS257 monochromatic unit, and a Keithley 2400 source meter. The light source of monochromatic light was a tungsten-halogen lamp(Oriel) and the light source of AM1.5 is an Xenon lamp equipped with AM0 and AM1.5 filters.

3. Results and discussion

The chemical structures of PEDOT-PSS, PCBM and MEH-PPV, together with the structure of the solar cells, are shown in Figure 1.

The absorption spectra of MEH-PPV, PCBM and a blend MEH-PPV/PCBM (1:4 by weight) as well as external quantum efficiency (EQE) of the solar cell are depicted in

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Figure 2. This figure shows that the EQE of the blend is consistent with a linear superposition of the absorptions from MEH-PPV and PCBM films.

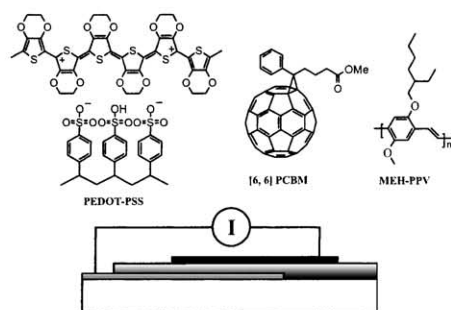


Figure 1 The chemical structures of PEDOT-PSS, PCBM, MEH-PPV (top) and the structure of solar cells (bottom).

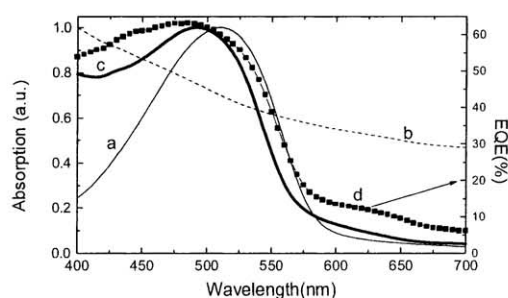


Figure 2 The absorption spectra of MEH-PPV (a), PCBM (b) and blend MEH-PPV with PCBM (c). The EQE of the solar cell with blend active layer as a function of wavelength is also depicted in the figure 2 (d).

One of the main factors limiting the power conversion efficiency (PCE) of polymer solar cells is low charge carrier mobility. The I-V characteristics of the solar cell under AM1.5 illumination (78 mW/cm^2) are shown in Figure 3 (line with square). Under ambient condition, the short circuit current density (I_{sc}), open-circuit voltage (V_{oc}), fill factor, and PCE of the blend cell were calculated to be 3.2 mA/cm^2 , 640 mV , 0.45 , and 1.2% , respectively. The fill factor of the blend device of MEH-PPV/PCBM has been improved, compared to that of stratified bi-layer diodes made of the same materials [6], which maybe attributed to the continuous pathway for charge transportation from the anode to cathode. On the contrary, the open-circuit voltage of the blend is 110 mV less than that of the bi-layer photodiode. It was observed that depositing of a thin layer of LiF (9 \AA) between the active layer MEH-PPV:PCBM and the Al cathode improves the performance of the solar cell. The I-V curve of the blend solar cell with LiF is depicted in Figure 3 (line with circles). Photovoltaic parameters calculated from this curve give an open-circuit voltage of 760 mV , a fill factor of 0.50 , and PCE of 1.3% . All these parameters have shown an improvement compared with those obtained from the

reference devices without using LiF. It suggests that LiF can play an important role to free charge collection at the electrode. However, the deposition of LiF resulted in a 0.5 mA/cm^2 decrease in photocurrent density.

Oxygen is highly reactive with fullerene and hence decreases the mobility of charge carriers. This indicates that further improvement of the cell performance can be possibly achieved through protective environment both when fabricating and characterising solar cells.

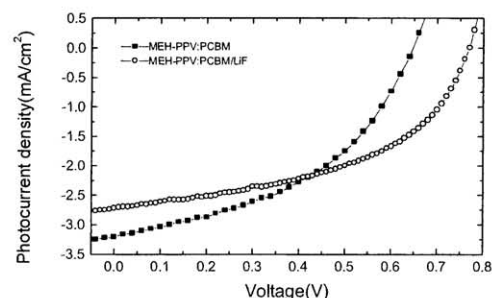


Figure 3 Photocurrent densities of the solar cells based on MEH-PPV and PCBM under AM1.5 illumination (78 mW/cm^2) (square symbols), for a comparison, the result of solar cell with insert LiF is also shown in figure 3 (circle symbols)

4. Conclusions

We demonstrate that polymer/molecule blend devices give improved performance than the bi-layer devices. Besides, it has been shown that further device optimisation can be achieved by improving charge collection using LiF, which enabled obtaining a power conversion efficiency value of 1.3% . Sample preparation and all characterisations were done under normal atmosphere, and no encapsulation was used for all devices.

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